Space Technology Research Grants

Efficient and Scalable Fabrication of Solid Oxide Fuel Cells via 3D-Printing

Completed Technology Project (2017 - 2021)

Project Introduction

Although solid oxide fuel cells (SOFCs) are a source of both efficient and clean electricity, the brittle ceramic materials which comprise them are difficult to form into complex architectures. Even in this simple geometry, the individual cell components must be fabricated separately and assembled by hand, meaning that cells, interconnect layers, and gas seals must be brought into contact by mechanically compressing them using heavy end-plates and bolts, which contribute substantially to the weight, cost, and assembly time of the SOFC stacks, and precluding their use in mobile applications such as space travel.For these reasons, a new approach is required for the manufacture of SOFCs, which will be capable of fabricating entire, monolithic fuel cell stacks in a single step without the need for subsequent assembly. The Tissue Engineering and Additive Manufacturing (TEAM) Lab led by Prof. Ramille Shah at Northwestern University has recently developed a new 3D-printing technique called 3D-Painting, which enables a single, extrusion-based platform to rapidly 3D-print hundreds of different materials from liquid, particle-laden 3D-inks. 3D-printed ceramic structures undergo thermal processing to achieve binder burn-out and particle sintering according to a low-temperature firing protocol. For this process to successfully create high-quality SOFCs, each individual material within the 3D-printed structure must undergo a similar degree of shrinkage resulting from binder-burnout and sintering to prevent cracking, warping, or delamination of the final structure, and must furthermore achieve a specific microstructure to enable the component's function. This requirement is non-trivial, considering that different microstructural characteristics must be simultaneously attained for individual materials/components during single-step firing, all while maintaining consistent shrinkage between materials. I propose to develop a quantitative, empirical model which will describe the influence of 3D-ink composition (particle volume fraction) and pore-formers (e.g. graphite) on the resulting sintered microstructures (porosity, pore tortuosity, mechanical strength) and volumetric reduction of single and multi-ceramic 3D-printed structures. Using this knowledge, I will design a series of optimized 3D-inks that can be 3D-printed and reduced-temperature fired into monolithic, multi-ceramic, functional SOFC structures consistent with the described microstructural and shrinkage criteria. After this, I propose to characterize the function of both single SOFCs and small SOFC stacks consisting of three to five SOFCs created using 3D-Painting and evaluate the electrochemical performance and microstructural evolution of individual components resulting from single and multi-cycle cell activity.

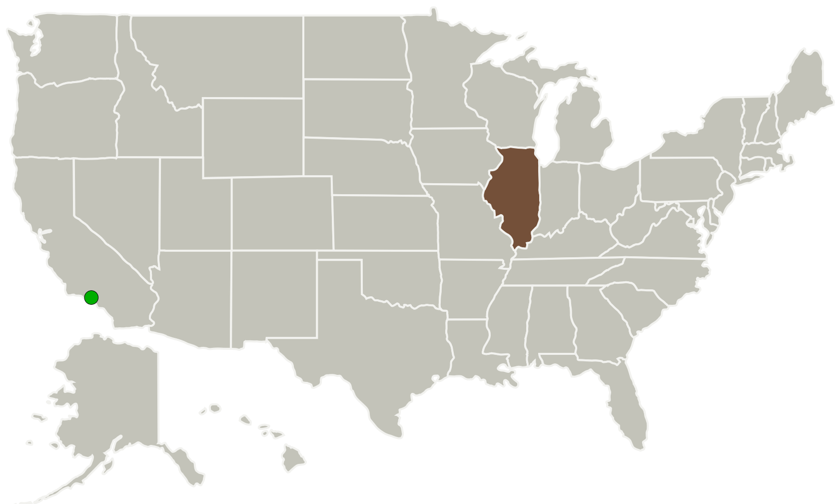
Anticipated Benefits

This approach for the manufacture of SOFCs will be capable of fabricating entire, monolithic fuel cell stacks in a single step without the need for subsequent assembly.

Efficient and Scalable Fabrication of Solid Oxide Fuel Cells via 3D-Printing

Table of Contents

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Northwestern University	Lead Organization	Academia	Evanston, Illinois
Jet Propulsion Laboratory(JPL)	Supporting Organization	NASA Center	Pasadena, California

Primary U.S. Work Locations
Illinois

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Northwestern University

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Scott Barnett

Co-Investigator:

Nicholas R Geisendorfer

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**

1 2 3 4 5 6 7 8 9

Applied Research | Development | Demo & Test

Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  - └ TX12.4 Manufacturing
    - └ TX12.4.2 Intelligent Integrated Manufacturing

Target Destinations

Earth, The Moon, Mars